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The Cryosphere Discussions

Interactive comment on "Layer disturbances and the radio-echo free zone in ice sheets" *by* R. Drews et al.

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The submittal by Drews et al. tackles the difficult problem of elucidating the cause of a negative result, the lack of radar reflections in the so-called echo free zone (EFZ) that occurs in many profiles in Greenland and Antarctica between the lowest detectable internal reflector and the bed echo. While this phenomena has been noted for many years in records from different radar systems, the authors correctly recognize that EFZ's in all data may not be caused by the same phenomena, though they do point out some generalities about the flow regime that seem relevant. In this paper their scope is the region around the EPICA DML core location where they have the benefit of several different kinds of direct information from the deep ice core: DEP records, changes in crystal orientation fabric (COF) and line-scan images that reveal the stratigraphy of

high-scattering zones called cloudy bands (CB's) which they propose are a "proxy" for RES horizons.

The authors' preferred explanation for the EFZ at DML is disruption of the internal stratigraphy by ice flow. Potentially competing mechanisms are (1) simply running out of signal strength to yield echoes from the deepest layers (the S/N problem) and (2) signal attenuation due to warmer ice near the bed. These two issues are dealt with, for the most part successfully, while the case is made for flow-related disturbance. Whether or not they have it exactly right, I think the paper sheds new light on the issue of the EFZ and its causes, and is a worthwhile contribution to the literature on the subject. The distortions seen in the CB data, together with the COF and DEP records provide good evidence that the loss of radar signals coincides, if not precisely, at least generally, with changes measured in the ice core. The paper is well-written with clear explanations and the topic should be of interest to many readers of The Cryosphere.

One troublesome issue for me is that the core sections in Figure 2, while showing the progression to more and more disturbed stratigraphy, also show evidence for many undisturbed layers near the highlighted sections, even in the deepest section. The authors point this out as well. There is also the problem of extrapolating layer structure from a 10 cm core to a region as wide as the Fresnel Zone, several tens of meters. Folding or layer disruption that is limited to a 10 cm zone can cause fading of echo strength but it would need to persist at larger spatial scales to remove layers entirely. There is no way to discern this with a single ice core record. Related to this is the problem that onset of the disturbed CB stratigraphy is not abrupt, while this seems to be a characteristic feature of the EFZ. The crux of this argument is on page 314 near the middle and I address it in the more detailed comments that follow.

I have two comments specifically about the figures and their captions that need correction or clarification followed by (mostly) editorial comments and suggestions with a reprise of several points from the previous paragraph.

Figure 1 Only one of the traces from Figure 3 is labeled and it has a different number here than in Figure 3 and its caption (6295 vs. 6297). Where is trace 4005 or 4205?

Figure 3 Same note about trace number 6295 vs. 97. Also the caption and the figure use different numbers for the second trace, 4205 and 4205. "... (c) and (d) Bedrock is visible in both traces at 2790." I see only a very weak bed echo in the 600 ns data just above the power axis. Is this what the authors mean? I don't see any bed echo at all in the 60 ns trace. If the bed echo is really that weak (or even absent) it certainly hurts the case the authors are trying to make that the EFZ is NOT an artifact of S/N.

Abstract line 11-12. The loss of dating is ancillary evidence for disturbed stratigraphy, but more than one sentence is needed to link this idea to the thread of the argument in the abstract (the sentence is abrupt and disconnected as is). Alternatively it could be dropped for brevity and the argument left for the body of the paper where the connection can be better made.

p. 309, 1-2 ...an abrupt transition, an upper onset that varies with depth. (depth is varying)

p. 309, 2-3 "Therefore ... " I don't see why a depth-varying upper onset argues against loss of sensitivity. (I'm objecting to the word "therefore"). Thermal effects can increase attenuation and might be expected to be related to proximity to the bed (as opposed to ice thickness).

p. 309, 24 Should probably have a reference for the correlation of CB's with impurity content, especially if they are not observed at many ice core sites as noted.

p. 310, 1 bands enable p. 310, 18 "aggravates" ?? p. 310, 25 are sparse

p. 311, 12-15 May want a reference for the age-depth values. p. 311, 18 But it's fair to note with respect to Figure 2 that many of the deep layers are not disturbed.

p. 312, 2 reflectors originate p. 312, 7 these are usually not continuous laterally p. 312, 7-8 ...display an example from profile 032137 (the figure caption says 033137).

p. 312, 13-16 This description evidently refers to a layer not readily discernable in Figure 1 but which is present in better renditions, providing an exception to the EFZ here (with similar exceptions noted elsewhere). I appreciate the authors' candor, but there should be a sentence introducing this caveat as such and perhaps another sentence or two arguing why such exceptions don't negate the general argument being made.

p. 312, 20-21 The parenthetical remark including "on the system side already" could be reworded for clarity. p. 312, 25-26 "...within a smaller vertical interval leading to some differences.

p. 313, 10 "One might also argue ..." This important discussion about temperature deserves the start of a new paragraph.

p. 313, 13 I'm not sure the temperature increase needs to be sudden if it's a threshold effect. Dielectric attenuation is temperature dependent. If weak returns are near the system S/N limit, a small change in temperature can make them unobservable.

p. 313, 15 "signal drops" rephrase

p. 314, 7-11 I don't understand the difference between "one-to-one" and "proxy." The word "approximate" needs to be here somewhere if I take the meaning correctly. But more importantly, here's where the argument moves from a 10 cm sample in the ice core to the first Fresnel zone and the authors should be clear that they can't see the waviness of the CB's over scales larger than a few cm. Also "increasing waviness" and "signals ... becoming... lost" does not seem consistent with the notion of an abrupt transition to the EFZ.

p. 314, 17 A reference for scattering studies based on Kirchoff approximation would be appropriate here.

p. 314, 21-22 "quantitative derivation ...is speculative." I think the authors mean that it would be speculative and so is not being undertaken, if I understand the argument.

p. 314, 26 border

p. 315, 8 similar to the GISP2 p. 315, 9 "...Jacobel and Hodge (1995) describe the coincident loss of internal layering in analog radar data at ...

p. 315, 15 Our data show the onset of the EFZ likely indicates .. (slightly less absolute)

Interactive comment on The Cryosphere Discuss., 3, 307, 2009.